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WATER SUPPLY AND WATER QUALITY CONTROL STUDY, EDWARDS UNDERGROUND RESERVOIR, TEXAS

Public Health Service
Dallas, Texas

January 1965

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WATER SUPPLY
AND
WATER QUALITY CONTROL STUDY
EDWARDS UNDERGROUND RESERVOIR
TEXAS

Study of Needs and Value of Storage
For Municipal and Industrial Water Supply
and Water Quality Control

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FEBRUARY 1965

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WATER SUPPLY

AND

WATER QUALITY CONTROL STUDY

EDWARDS UNDERGROUND RESERVOIR

TEXAS

Abstract

An investigation has been carried out which discloses the need for and value of storage for municipal and industrial water supply in the proposed Cloptin Crossing, Montell, Concan, and Sabinal Reservoirs. The latter three reservoirs are to be used to recharge the Edwards limestone fault zone aquifer which provides municipal and industrial water supply. A portion of the immediate and future needs for water in the study area can be satisfied from storage in these projects. The investigation further found need for water quality control in the San Antonio River downstream from San Antonio. Economic and demographic studies revealed a potential for increased industrial development and population growth, and serve as the foundation for the projected needs.

Prepared for

DEPARTMENT OF THE ARMY

U.S. Army Engineer District

Fort Worth, Texas

U.S. DEPARTMENT OF HEALTH, EDUCATION, AND WELFARE
Public Health Service, Region VII
Dallas, Texas

JANUARY 1965

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DEPARTMENT OF HEALTH, EDUCATION, AND WELFARE
REGIONAL OFFICE
1114 Commerce Street
Dallas, Texas 75202

PUBLIC HEALTH SERVICE

July 2, 1965

District Engineer
U. S. Army Engineer District, Fort Worth
P. O. Box 1600
Fort Worth, Texas 76101

Dear Sir:

Subject: "Water Supply and Water Quality Control Study, Edwards Underground Reservoir, Texas"

Reference is made to the Benefits Section and Appendix of the subject report, and more specifically to the benefits attributable to Montell, Concan, and Sabinal Reservoirs due to the increase in springflow from the Leona River Springs as shown on page 3 of the Appendix.

After consideration of data which have recently become available as discussed with your staff, it appears that the deeper Edwards Limestone formation is not an appropriate alternative and that these benefits might be better evaluated by using a single-purpose reservoir at the Montell site to yield 4,000 acre-feet per year (3.57 mgd). In addition, a channel dam and pipeline to provide conveyance of the water to the point of use near Uvalde, Texas would be required. This is the same method used to evaluate the 4.0 mgd of water to be delivered to downstream municipal and industrial users from Montell Reservoir via a pipeline as shown on page 5 of the Appendix.

Based on this method, the benefits attributable to the three recharge reservoirs, due to the increased springflow from Leona River Springs, would be $82,100 per annum. This is a net increase in annual benefits of $56,000 over that reported.

We therefore recommend that the total recharge benefits for these three reservoirs be increased by this amount. The revised total recharge benefits as shown on Appendix page 5 should then read as follows:

Reservoir	Total Annual Recharge Benefits
Montell	$1,034,000
Concan	835,500
Sabinal	613,900

These same changes should be noted on pages II-3 and IX-2 of the report.

The opportunity of providing these revisions is appreciated.

Sincerely yours,

Jerome H. Svore

Jerome H. Svore
Regional Program Director
Water Supply & Pollution Control

I. INTRODUCTION

Request and Authority

In a letter dated November 30, 1962, the U.S. Army Engineer District, Fort Worth, Texas, requested that the Department of Health, Education, and Welfare make necessary studies ". . . to determine the estimated water needs and value of the water for the area included in the authorized study (the Edwards Underground Reservoir area of Texas). . . ." This study is in accordance with provisions of (1) the Federal Water Pollution Control Act, as amended (33 U.S.C. 466 et seq.), and (2) a Memorandum of Agreement between the Department of the Army and the Department of Health, Education, and Welfare dated November 4, 1958.

Purpose and Scope

The purpose of the study is to estimate the water requirements for municipal and industrial and water quality control purposes in the Edwards Underground Reservoir area of Texas and the surrounding study area to the year 2075. Estimates are also made of the value of benefits attributable to the Federal reservoir projects which will provide storage of water for these purposes.

In addition to determining requirements, an area-wide plan for supplying these needs is developed, which provides for orderly and efficient utilization of potential water resources within the area, and gives full recognition to all permits, commitments, and agreements executed by local interests.

Acknowledgments

The cooperation of many persons and agencies is gratefully acknowledged. Special appreciation is expressed to the following:

Bureau of Business Research, University of Texas, Austin, Texas
Texas State Department of Health, Austin, Texas
Texas Water Commission, Austin, Texas
U.S. Army Engineer District, Fort Worth, Texas
U.S. Department of Agriculture, San Marcos, Texas

II. SUMMARY OF FINDINGS AND CONCLUSIONS

Summary of Findings

1. The study area comprises 14 counties in south Texas, 7 of which are in part underlain by the Edwards Underground Reservoir. It is generally coincident with the upper portions of three river basins: the Guadalupe, the San Antonio, and the Nueces.

2. The Edwards and associated limestones rank with some of the best aquifers in the country. The exceptionally high transmissibility of the fault zone aquifer permits the movement of ground water from one river basin to another.

3. The economy of the study area is highly diversified. Agriculture and manufacturing together accounted for 15.4 percent of the labor force in 1960.

4. The San Antonio Standard Metropolitan Statistical Area (SMSA) accounts for over 80 percent of the water use in the study area.

5. The water quality of the existing and firmly planned sources is acceptable for municipal, industrial, and agricultural uses.

6. The project design incorporates the following base streamflows in the system: (a) Most severe drought of record for reservoir (surface and ground) yields as determined by the Corps of Engineers, and (b) monthly low flows with an exceedence of 95 percent for calculating water quality control needs.

Conclusions

1. To insure continued growth, careful planning for efficient development of all of the study area's water resources is essential. Realization of the full potential of these resources for municipal, industrial, agricultural, and recreational purposes will be possible only if present and future pollution in the area is controlled. Since presently known methods of waste treatment cannot accomplish this control, some means of maintaining minimum quality conditions in the area's waters must be made a part of the water supply plan.

2. The study area's population is expected to grow to 2,950,000 by the year 2025, and 4,620,000 by the year 2075, from a base of 846,000 in 1960.

3. Estimated future municipal and industrial water supply needs for the study area are 689 million gallons per day (mgd) in the year 2025 and 1,167 mgd in 2075.

4. With the water supply plan as presented herein, the potential water resources located within the study area are sufficient to satisfy all estimated area municipal and industrial water requirements until the year 2000. The addition of the tentative quantity of 180,000 acre-feet per year (161 mgd) from the proposed Cuero Reservoir (Guadalupe River, mile 110.8) will provide sufficient water to supply all municipal and industrial needs until the year 2018, at which time the area would become deficient. The projected irrigation needs to this time will be satisfied from direct use of municipal and industrial return flows.

5. To maintain water quality in the San Antonio River downstream from the study area will require a draft-on-storage of 123,000 acre-feet per year in the year 1970; 280,000 acre-feet per year in the year 2025; and 454,700 acre-feet per year in the year 2075, assuming 85 percent removal of biochemical oxygen demand (BOD) and a low streamflow with a recurrence interval of 20 years. No source of water to meet this requirement was found in the study area ; therefore, maintenance of good water quality in the San Antonio River will be contingent on development of highly efficient advanced waste treatment and water reuse techniques.

6. The three proposed recharge reservoirs will have no effect on the quality of the Edwards Underground water, since the waters to be impounded to recharge the aquifer are from the same source streams as the present uncontrolled recharge water.

7. Minimum annual project water supply benefits based on alternative costs (See Appendix) are as follows:

Reservoir	Water Supply Benefits
Cloptin Crossing	$ 653,000
Montell	1,098,800
Concan	816,800
Sabinal	600,100

Since need for the project reservoirs is immediate, the above values have not been discounted. The value of benefits was determined as being equal to the cost of the most likely alternate source of water supply that would be used in the absence of the project.

III. PROJECT DESCRIPTION

Location and Purpose

The project consists of four reservoirs located in two river basins as shown in figure III-1 located at the back of this report. One of the proposed reservoirs, Cloptin Crossing, is a conventional multiple-purpose project located in the Guadalupe River basin. The remaining three, Montell, Concan, and Sabinal, all in the Nueces River basin, are designed to increase the yield of the Edwards limestone fault-zone aquifer through recharge. This recharge is to be accomplished by releasing waters from the joint storage pools for flood control and recharge purposes. These surface releases would be absorbed by the aquifer as they flow downstream through a zone where the streambeds and the Edwards limestone aquifer are hydraulically connected.

Pertinent Data

Pertinent data for the four project reservoirs are shown below in table III-1. Also included is the pertinent data for Dam Number 7 Reservoir which is recommended for local interest construction.

In addition, Canyon Reservoir at mile 303.0 of the Guadalupe River has been constructed by the Corps of Engineers. Deliberate impoundment began on June 16, 1964. This project has a conservation pool capacity of 366,400 acre-feet and a yield of 86.0 mgd. Other study area reservoirs with conservation pool capacities in excess of 5,000 acre-feet are Dunlap, McQueeney, and H-4, all power projects in the Guadalupe River basin, and Medina Lake, an irrigation project in the San Antonio River basin. Although it is located outside the study area, the proposed Cuero Reservoir (Guadalupe River, mile 110.8) is expected to provide an additional water supply of 161 mgd or 180,000 acre-feet per year to the study area.

Table III-1

Pertinent Data

Reservoir	River Mile	Stream	Basin	Conservation Storage (1,000 ac./ft.)	Joint-Storage FC & Recharge (1,000 ac./ft.)	Increased Resources for Recharge (mgd)	Dependable Yield (mgd)
Montell	401.6	Nueces	Nueces	1.0	239.3	23.7	4.0 a/
Concan	226.2	Frio	Nueces	-	141.2	19.2	-
Sabinal	42.3	Sabinal	Nueces	-	89.1	14.1	-
Cloptin Crossing	32.5	Blanco	Guadalupe	274.9	-	-	38.0
Dam No. 7 b/	351.3	Guadalupe	Guadalupe	640.5	-	-	41.0 c/

a/ Used to satisfy existing downstream appropriated water rights by passing the yield around the recharge zone via a pipeline.

b/ Recommended for local interest construction.

c/ Net increase of Canyon-Dam No. 7 Reservoir system over that yield determined for Canyon Reservoir without upstream development.

Source: Corps of Engineers 1/

Recharge Data

The Corps of Engineers, in making routings for determining the yield of the Edwards fault-zone aquifer, used a control elevation of 612 feet mean sea level (m.s.l.) in Bexar County Well H-26 (Beverly Lodges). See figure III-1 for the location of this observation well. This is considered the lowest safe water level in the aquifer and was previously reached in the year 1956, when the underground reservoir was dewatered to its lowest historical level. Chances are that lowering of the water level below this control elevation would increase the possibility of intrusion of highly mineralized water which is found to the south of the highly pumped zone in the San Antonio area.

These routings indicate a recharge of 423,200 acre-feet per year through the routing period of 1935-1956 under existing conditions of recharge. With the recharge reservoirs in operation, the period recharge would be 487,100 acre-feet per year, which represents an increase of 63,900 acre-feet per year. This increase is divided between spring flow and pumping as shown in table III-2.

The proposed recharge reservoirs should have no effect on ground water quality in the Edwards limestone aquifer, since natural recharge to the aquifer is from the same streams and in the same places.

Table III-2

Average Annual Discharge of Edwards Fault Zone Aquifer Through Period of Routing, 1935-1956

Mode of Discharge	Existing Conditions	With Recharge Reservoirs	Increase
Pumping	234,000	263,000	29,000
Spring Flow*	285,900**	320,800	34,900***
Total	519,900	583,800	63,900

*For purposes of this report, spring flow is assumed to consist of Comal, San Marcos, and Hueco Springs in the Guadalupe River basin; San Antonio and San Pedro Springs in the San Antonio River basin; and Leona Springs in the Nueces River basin.

**Under assumed conditions of constant pumping of 234,000 acre-feet per year during period of routing. The total average annual spring flow for the period 1935-1956 was 352,400 acre-feet.

***The increase of 34,900 acre-feet per year is divided among the springs as follows: (1) Comal, San Marcos, and Hueco Springs, 17,600 acre-feet per year; (2) San Antonio and San Pedro Springs, 13,300 acre-feet per year; and (3) Leona River Springs, 4,000 acre-feet per year.

Source: Corps of Engineers 1/

IV. STUDY AREA DESCRIPTION

General

The study area comprises 14 counties, 7 of which are in part underlain by the Edwards Underground Reservoir of Texas. Also, the area is generally coincident with the upper portions of three river basins: the Guadalupe, the San Antonio, and the Nueces. (See figure III-1.) The study area, which comprises over 5 percent of the land area of the State of Texas, is located between 97° and 101° west longitude, and 29° and 30° north latitude, and includes the San Antonio SMSA.

Geography

Blanco, Comal, Kendall, Kerr, Edwards, Real, Bandera, and Hays Counties are located on the Edwards Plateau, which is a limestone highlands with deeply eroded valleys. The soils of the plateau are thin and stony, generally limiting agriculture to ranching. Caldwell and Guadalupe Counties are in the blackland prairie region, a gently rolling area which was originally a grasslands but now supports cotton, corn, sorghums, small grains, and forages. Northern Bexar, Medina, Uvalde, and Kinney Counties are on the Edwards Plateau and their southern portions lie within the Gulf Coastal Plain region, which has deep sandy soil generally covered by mesquite and dwarf oak. This latter area is used primarily for raising livestock.

The climate of the study area can best be described as varying from semiarid to subhumid. The mean annual rainfall ranges from 22 to 39 inches. Average annual temperatures vary from 64° to 69° and the average length of the growing season is 221 to 279 days.

Runoff within the area is characterized by large variations annually as well as seasonally. Due to the interchange between surface and ground waters, however, exact measurements of surface runoff are difficult to determine. In most streams, with the exception of those whose base flows are spring-fed, periods of zero flow have been experienced.

Characteristics of the Subareas

The study area was divided into three subareas for the purpose of providing suitable size base areas for study, at the same time maintaining a reasonable degree of homogeneity of economic, water resource, and geographic factors.

The principal characteristics of each of the subareas are shown in table IV-1.

Table IV-1

Characteristics of the Subareas

Item	Sub-area I	Sub-area II	Sub-area III
Counties	Blanco Caldwell Comal Guadalupe Hays Kendall Kerr	Bandera Bexar	Edwards Kinney Medina Real Uvalde
Principal Cities	Johnson City Lockhart New Braunfels Seguin San Marcos Boerne Kerrville	San Antonio Bandera	Rock Springs Brackettville Uvalde Sabinal Leakey Hondo Castroville
1960 Population	112,363	691,043	42,566
Economy	Ranching Farming Oil Tourist	Manufacturing Ranching Farming Tourist	Ranching Tourist
Topography	Mountainous to level rolling	Hilly to undulating	Rugged to rolling plains
Altitude (ft. m.s.l.)	600 to 1,850	500 to 2,400	600 to 2,500
Annual Rainfall (inches)	30.1 to 33.8	27.9 to 29.0	22.0 to 28.6
Mean Annual Temperature (deg. F.)	64 to 68	65 to 67	65 to 69
Growing Season (days)	221 to 269	250 to 279	222 to 274

Source: A. H. Belo Corporation 2/

V. WATER RESOURCES OF THE STUDY AREA

Ground Water 3-11/

Ground water conditions in the study area are of primary importance, since three of the project reservoirs are to be used for ground water recharge.

The geologic units in order of importance as aquifers in the study area are the Edwards and associated limestones, the Glenrose limestone, the Travis Peak formation of the Trinity group, and the Leona formation, the Austin Chalk, Hosston and Sligo formations, rocks of the Taylor and Navarro groups, the Carizzo sand, and the rocks of the Wilcox group.

The Edwards is a dense, hard limestone, but on weathering the rock is extensively honeycombed and cavernous. Where it is exposed, conditions are favorable for a direct infiltration of rainwater and streamflow. Wells that penetrate fractures obtain large yields, but others may yield little or no water. Wells in the so-called Edwards limestone fault-zone aquifer yield 1,500 gallons per minute on the average. The exceptionally high transmissibility of the fault-zone aquifer permits the movement of ground water from one river basin to another. The Edwards limestone-Trinity sands aquifer supplies the base flow in many of the perennial streams which in turn supply much of the recharge of the fault zone. The Edwards limestone-Trinity sands under the Edwards Plateau, north and west of the fault zone, yield an average of 400 gallons per minute per well.

The Glen Rose limestone crops out north of the Balcones fault zone and its yields are small to moderate.

The Leona formation consists of alluvium and terrace deposits in the valleys of the major streams. Its importance as an aquifer is restricted to Leona River valley southeast of the city of Uvalde, where some wells yield enough water for irrigation. Evidently there is a hydraulic connection between Leona and Edwards formations in this area, and production from the Leona is dependent on the artesian head in the Edwards.

The Cow Creek limestone of the Travis Peak formation yields moderate quantities of water in Comal and Kendall Counties. Near Uvalde, and locally near San Antonio, the Austin Chalk yields moderate quantities of water similar in chemical quality to the water in the Edwards limestone, suggesting a hydraulic connection (probably through faults).

The Carrizo-Wilcox sands underlie the blackland south and east of the fault zone, and have available moderate quantities of water.

The average yield per well in the Carrizo-Wilcox sands is 500 gallons per minute.

Principal springs in the area are the Leona River Springs near Uvalde, San Antonio and San Pedro Springs at San Antonio, Hueco and Comal Springs at New Braunfels, and San Marcos Springs at San Marcos. During the 1955 to 1957 period, all of the springs except San Marcos ceased flowing during part of the time.

Surface Water

Records of the streamflow in the study area vary in length, from 47 years for the Frio River near Derby, Texas, to 1 year for Salado Creek at San Antonio. Discharge frequency analyses were made at various points along the several streams in the study area. The results of these analyses are shown in table V-1.

Water Quality

A resume of surface water mineral quality for the study area is presented in table V-2. The mineral quality of study area surface waters can be generally described as good.

Ground water quality may also be generally described as good, except for high total dissolved solids in the Carrizo-Wilcox sands and high natural fluorides in some of the wells. Chemical characteristics of ground water are shown in table V-3. 12/ The recharge reservoirs should have no effect on ground water quality in the Edwards limestone aquifer, since the zones of recharge and sources of recharge water will not be changed.

Table V-1

Discharge Frequency Analyses

Location	Drainage Area sq. mi.	River Mile	Years of Record	Annual Average Flow at Various Exceedence Intervals (cfs) 50%	80%	90%	95%	98%
Guadalupe River at Comfort	836	397	22	98	58	36	23	10
Guadalupe River near Spring Branch	1,282	334	39	192	94	64	47	33
Guadalupe River above Comal River at New Braunfels	1,516	281	33	320	116	63	44	26
Comal River at New Braunfels	117	1.1	29	320	220	141	88	45
Plum Creek near Luling	356	--	31	85	27	15	9	5
Medina River near Pipe Creek	457	--	20	85	26	24	8	5
Medina River near San Antonio	1,225	5.2	22	100	41	20	15	12
Hondo Creek near Hondo	132	--	9	12	4	1	0	0
Sabinal River near Sabinal	206	--	19	15	5	2	1	0
Frio River at Concan	405	--	36	69	32	21	15	10
Frio River near Derby	3,493	--	46	63	22	13	7	3
West Nueces River near Bracketville	700	--	16	15	1	0	0	0
Nueces River near Laguna	764	395	38	108	57	41	31	23
Nueces River below Uvalde Creek	947	366	22	38	14	6	4	2
Cibolo Crk. near Falls City	831	9	31	82	39	25	16	10
San Antonio River below confluence with Medina River	--	--	36	76	38	27	21	16

Source: Geological Survey 13 14/

Table V-2

Surface Water Mineral Quality

Location	River Mile	Number of Samples	Average Values in mg/l		
			Total Dissolved Solids*	Chlorides	Sulfates
Guadalupe River near Comfort	397	126	302	24	22
Guadalupe River near New Braunfels	279	120	297	22	22
Guadalupe River near Seguin	256	90	325	30	27
N. Fork of Guadalupe River near Kerrville	425	110	261	20	12
Comal Creek near New Braunfels	1	113	305	19	24
San Marcos River near Luling		96	423	65	42
San Marcos River near San Marcos		103	307	22	24
Blanco River near Wimberly		102	263	21	25
Cibolo Creek near Schertz	60	119	399	45	42
San Antonio River near San Antonio	220	120	494	74	72
San Antonio River between San Antonio and Falls City	181	127	496	76	83
Medina River near Castroville	45	109	312	24	52
Medina River near San Antonio	8	119	481	68	98
Nueces River near Laguna	395	111	252	21	14
Nueces River near Tom Nunn Hill	366	114	264	24	24
Frio River near Concan	224	109	302	20	16
Frio River near Leon River	128	82	381	71	49

* Residue at 105°C.

Source: Texas State Department of Health 15/

Table V-3

Ground Water Quality (mg/l)

Item	Source: City : County:	Blanco Blanco	Kyle Hays	San Marcos Hays	Luling Caldwell	Lockhart Caldwell	New Braunfels Comal	Marion Guadalupe	San Antonio Bexar
Total Dissolved Solids (Residue at 105°C.)		370	494	356	1,250	515	284	388	296
Hardness as $CaCO_3$		491	363	305	[illegible]	290	250	400	264
Calcium		94	78	66	[illegible]	70	70	120	69
Magnesium		63	37	31	[illegible]	17	18	28	18
Sodium		22	30	12	231	[illegible]	9	8	16
[illegible]		[illegible]	[illegible]	[illegible]	[illegible]	[illegible]	10	[illegible]	13
Sulfate		113	131	28	131	80	33	8	32
Chloride		25	28	29	178	88	21	79	19
Fluoride		3.2	3.2	0.4	0.3	0.2	0.2	1.1	0.3
Nitrate		---	---	8.0	.04	0.4	3.7	27.0	3.7
Date		1/50	10/49	4/60	4/57	4/55	7/56	1/60	---
Class of Analysis		Typical	Typical		Typical	Typical	Typical	Typical	Average

Source: Texas State Department of Health 17/

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VI. THE ECONOMY

Determination of future water requirements for the study area involves appraisal of the area's population and industrial growth potential. Estimation of future growth patterns of the study area, therefore, are made by (1) a comparison of past trends between the study area, the State of Texas, and the United States on three basic measures; income, employment, and population, and (2) a detailed analysis of specific economic activity of agriculture, mining, and manufacturing, with special emphasis given to those industries which will have the greatest effect on future water requirements of the study area.

Present

Extractive Industries

Mining

The principal minerals in the study area are petroleum, natural gas, stone, sand and gravel, lime, and clays. A total of 302,023,811 barrels of crude oil has been produced in the study area since petroleum was first discovered in 1889. The 1958 production of crude oil in the study area was 7,907,891 barrels, which was 0.86 percent of the State's production. 1/ The value of mineral production between the years 1952 and 1961 is shown in table VI-1.

Table VI-1

Value of Mineral Production in the Study Area, 1952-1961
(1,000's of 1960 dollars)

Year	Total Study Area	Sub-area I	Sub-area II	Sub-area III
1952	32,085	18,845 1/	9,228	4,012 1/
1953	31,351	21,093	9,135	1,123
1954	39,602	23,966	13,265	2,371
1955	43,373	25,072	15,663	2,638
1956	44,095	25,492	15,840	2,763
1957	37,816	23,813 1/	13,392	611 1/
1958	41,248	24,270 1/	16,462	516 1/
1959	49,780	25,644 1/	20,081	4,055
1960	42,746	25,076 1/	16,932	738 1/
1961	40,211	21,037 2/	18,235	939 1/

1/ To avoid disclosure of individual company operations, one county is not included.

2/ To avoid disclosure of individual company operations, three counties are not included.

Source: Bureau of Mines 16/

Agriculture

In terms of income and employment, agriculture is the leading extractive industry in the study area. Although agricultural employment decreased 31 percent between 1950 and 1960, the value of agricultural output increased 32 percent. The value of farm products sold per agricultural employee has risen 91 percent in the decade between 1950 and 1960. As shown in table VI-2, agricultural output was valued at 69,674,063, 1960 dollars in 1959. 17/ The sale of livestock and livestock products accounted for over 77 percent of this value. Most of the income from livestock and livestock products resulted from the sale of wool, mohair, beef, and poultry. An appreciable increase in cattle feeding in the study area has occurred in recent years.

Major crops grown in the area include cotton, corn, grain sorghums, and vegetables. A shift of some cropland to pasture in order to accommodate a more diversified livestock program has occurred in recent years. Total irrigated land increased from 21,331 acres in 1949 to 42,529 acres in 1959. Over 86 percent of the land was irrigated from ground water sources in 1959.

Table VI-2

Agricultural Statistics for the Study Area
1944, 1949, 1954, and 1959

Item	1944	1949	1954	1959
Number of Farms	15,397	13,930	13,026	10,281
Land in Farms (1,000 acres)	8,319	8,340	3,299	7,511
Cropland Harvested (1,000 acres)	725	728	498	578
Pastureland (1,000 acres)	7,448	7,303	7,492	7,354
Value of Livestock and Livestock Products Sold*	33,872	37,705	38,038	53,847
Value of Crops Sold*	9,285	15,193	9,384	15,743
Value of Forest Products Sold*	99	72	50	84
Total Value of Farm Products Sold*	43,256	52,970	47,472	69,674
Number of Farms Irrigated	668	404	499	497
Land in Irrigated Farms (1,000 acres)	--	272	735	663
Irrigated Cropland Harvested (1,000 acres)	--	14	23	32
Other Irrigated Land (1,000 acres)	--	7	18	11

*All values in 1,000's of 1960 dollars.

Source: Bureau of the Census 17/

Manufacturing

Manufacturing employment in the study area increased 104 percent or 14,300 in the two decades from 1940 to 1960. This compares with a statewide increase of 154 percent for the same two decades. Although the study area exhibits a diversified manufacturing base, the bulk of the industries at present are engaged in the manufacture of textiles, food and kindred products, and fabricated metals. These industries accounted for about 65 percent of the manufacturing employment in 1960. Other manufacturing industries worthy of mention include stone and clay, printing and publishing, furniture, and some nondurable goods. Data on manufacturing activities for the study area are shown in table VI-3.

Table VI-3

Manufacturing Activity in the Study Area
1939, 1947, 1954, and 1958

Item	1939	1947	1954	1958
Number of Establishments	400	553	680	696
Number of Employees	--	17,927	21,196	23,859
Value Added by Manufacturing (1,000's of 1960 dollars)	59,520	96,880	138,840	182,346

Source: Bureau of the Census 18/

Generally an increase in employment, coupled with increased value added per employee, reflects favorably on the prospect for continued growth in the manufacturing industries.

Service Industries

Service industries constitute a large segment of the economic activity of the study area. They employed 63 percent and 79 percent of the total labor force in 1940 and 1960, respectively. The high 1960 percentage in the study area can be attributed to relatively more employees in government and the large numbers of armed forces personnel based in the area.

Labor Force and Employment

Changes in the study area labor force between 1940 and 1960 can be readily seen in table VI-4. The most notable changes in employment which occurred are: (1) An increase of manufacturing employment which is below the rate of increase for the State of Texas. Between 1940 and 1960, manufacturing employment increased 104 percent. Manufacturing employment accounted for 10.2 percent of the study area

labor force in 1960. (2) A decrease of workers in agriculture. The study area showed a decrease of 50 percent in agricultural employment between 1940 and 1960, while Texas agricultural employment decreased 64 percent. (3) Unemployment has decreased from 13.6 percent of the labor force in 1940 to 4.7 percent of the labor force in 1960. During the same period, total labor force has increased from 190,587 to 273,671.

Table VI-4

Labor Force and Employment Summary
for the Study Area, 1940, 1950, and 1960

Item	Labor Force					
	1940		1950		1960	
	Percent	Number (1,000's)	Percent	Number (1,000's)	Percent	Number (1,000's)
Agriculture and Forestry	14.9	28.4	9.5	20.7	5.2	14.2
Mining	1.1	2.1	1.0	2.2	0.9	2.5
Manufacturing	7.2	13.7	10.0	21.8	10.2	28.0
Resource Oriented	4.7	8.9	5.7	12.4	5.4	14.9
Furniture, Lumber and Wood Products	0.5	1.0	0.7	1.5	0.6	1.9
Primary Metals	0.5	1.0	0.2	.4	0.2	.5
Food & Kindred Products	2.3	4.3	2.9	6.4	2.9	8.0
Chemical & Allied Products	0.2	.4	0.2	.4	0.2	.5
Stone, Clay & Glass	0.5	1.0	1.0	2.2	0.9	2.4
Other Nondurables	0.7	1.2	0.7	1.5	0.6	1.6
Nonresource Oriented	2.5	4.8	4.3	9.4	4.8	13.1
Fabricated Metals, Transportation & Other Durable Goods	0.6	1.1	1.2	2.6	1.8	4.9
Textiles & Apparel	1.0	2.0	1.9	4.2	1.8	4.9
Printing, Publishing & not Elsewhere Classified	0.9	1.7	1.2	2.6	1.2	3.3
All Other Employment (Services)	63.2	120.5	75.5	164.6	79.0	216.1
Unemployed	13.6	25.9	4.0	8.7	4.7	12.9
Total Labor Force (1,000's Workers)		190.6		218.0		273.7

Source: Bureau of the Census 19/

Tourism and Recreation

The considerable income that the study area derives from tourism and recreational activities is worthy of note in this discussion of the economy of the study area. Resources which promote these activities include spring-fed, perennially flowing streams, scenic mountainous

woods, numerous caves and caverns, and State parks. Game (deer, wild turkey, quail, dove, and sport fish) is also plentiful in most of the study area. These factors have attracted dude ranches, hunting and fishing resorts, and generally have favored the growth of the tourist industry. Aside from attracting outside visitors, the location of these excellent tourist and recreational facilities is convenient for the residents of San Antonio, Austin, and other large Texas cities.

Population

Study area population increased from 328,342 in 1920 to 845,972 in 1960 as shown in table VI-5. 20/ This represents an annual growth rate of approximately 2 3/8 percent, compared to an annual rate of 1 13/16 percent for the State of Texas during the same period. The urban component of the population with a growth rate of 3½ percent is also presented in table VI-5. 20/

Table VI-5

Historic Population for the Study Area
1920-1960

Year	Total Population	Urban Population
1920	328,342	180,743
1930	438,376	274,894
1940	480,801	303,901
1950	648,117	511,867
1960	845,972	721,812

Source: Bureau of the Census 20/

The Future

Mining activity is expected to continue to increase at approximately the same growth rate experienced between 1940 and 1960. This level of output can be sustained by presently known reserves using new methods of secondary recovery of petroleum.

Agriculture is expected to continue increasing its output although the labor force utilized in this endeavor can be expected to decrease. This greater output will be the result of improved technology and increased productivity in agriculture. As the result, higher agricultural incomes are expected. It is anticipated that an expanding population, higher income, a higher standard of living, and changing tastes of consumers will provide for continued growth in the livestock industry.

The segment of the economy dedicated to manufacturing is expected to expand primarily in the nonresource-oriented industries. Manufacturing employment is expected to represent 13.8 percent of the labor force by the year 2025.

The service industries, which include sales, insurance, finance, personal services, and transportation, employed 79 percent of the labor force or 216,096 workers in 1960. Based on past trends, modified by relative growth and income in the area, comparable employment in the year 2025 will be about 768,000, or 81 percent of the labor force.

A summary of the present and future employment is shown in table VI-6.

Table VI-6

Labor Force and Employment for the Study Area
1960, 2025, and 2075

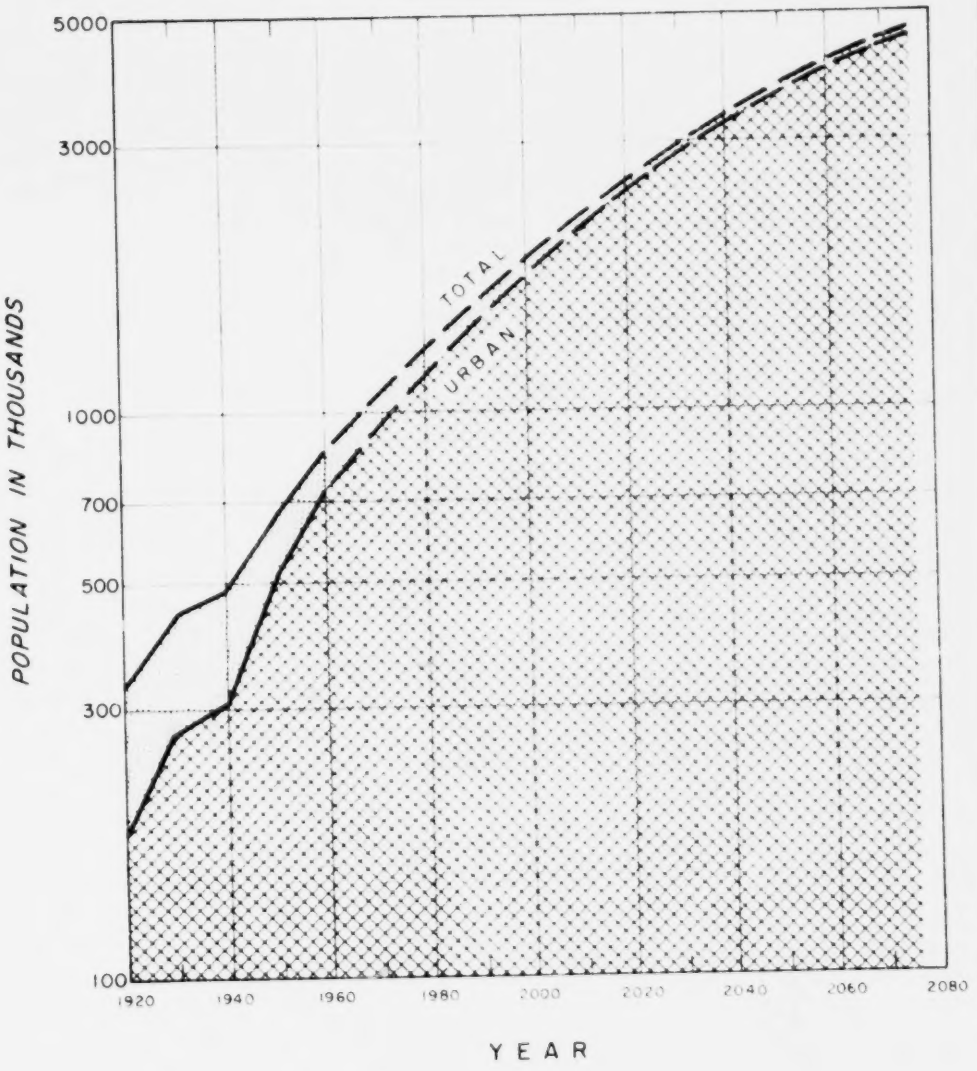
Item	Percent of Labor Force		
	1960	2025	2075
Agriculture & Forestry	5.2	1.2	0.8
Mining	0.9	0.4	0.3
Manufacturing	10.2	13.8	13.5
Resource Oriented	5.4	5.0	4.9
Furn., Lumber & Wood	0.5	0.4	0.4
Primary Metals	0.2	0.3	0.2
Food & Kindred Products	3.0	2.8	2.8
Chemicals & Allied Products	0.2	0.4	0.4
Stone, Clay & Glass	0.9	0.6	0.7
Other Nondurables	0.6	0.5	0.4
Nonresource Oriented	4.8	8.8	8.5
Fabricated Metals, Machinery, Transportation, and other Durable Goods	1.8	5.6	5.4
Textiles & Apparel	1.8	2.7	2.6
Printing, Publishing & not Elsewhere Classified	1.2	0.5	0.6
All Other Employment (Services)	79.0	80.6	81.4
Unemployed	4.7	4.0	4.0
Total Labor Force (1,000's of Workers)	273.7	952.9	1,660.0

Total population for the study area is expected to reach 2,949,700 by 2025 and 4,620,000 by 2075, as shown in figure VI-1 and table VI-7. Similarly, urban population is expected to reach 2,852,100 by 2025 and 4,521,000 by 2075. Many factors are considered in formulating the population projections. These include: (1) Resources and employment analysis; (2) the trend toward urbanization; (3) growth comparisons with cities that were of similar size to the cities of the study area in the recent past; and (4) the ratio of growth between study area cities and the State's urban population.

Table VI-7

Population for United States, Texas, and the Study Area, 1960, 2025, and 2075
(1,000's)

Year	United States	Texas	Study Area	
			Total	Urban
1960	179,977	9,580	846	722
2025	546,000	30,000	2,950	2,852
2075	790,000	54,000	4,620	4,521



WATER SUPPLY & WATER QUALITY CONTROL STUDY
EDWARDS UNDERGROUND RESERVOIR - TEXAS

POPULATION TRENDS & PROJECTIONS

U S DEPARTMENT OF HEALTH, EDUCATION, & WELFARE
Public Health Service
REGION VII DALLAS, TEXAS

FIGURE VI-1-A

VII. WATER REQUIREMENTS

General

The term water requirements encompasses a multiplicity of uses which are dependent upon a large number of variables. Although primarily concerned with water for municipal, industrial, and water quality control purposes, this study examines other water uses that affect the supply and demand for water within the study area. The probable future water requirements of the study area are based on economic projections, coupled with analyses of unit water requirements.

Types of Water Use

Municipal

Municipal water as defined here includes residential, commercial, public, and those industrial uses which can reasonably be reflected in a per capita use figure. Also included in the per capita quantities are losses in the distribution systems and treatment plant attentuation.

Industrial

The definition of industrial water use in this study refers to all water except that supplied from municipal systems which is used by the manufacturing industries (Standard Industrial Classification Categories 13, 14, and 20 through 39). 21/ The total industrial requirements are determined by combining the projected number of employees with the projected unit employee water use for each of the several industrial categories. The base data were obtained from a published survey of the study area, and adjustments have been made to reflect anticipated recirculation practices. 22/

Power Generation

Consumptive use of water for thermal power generation is a part of the industrial requirement that has been determined separately. Information on future water use was developed from estimates of area power companies, the Federal Power Commission, and the Edison Electric Institute for the Senate Select Committee on National Water Resources. Consideration was given to the general location of future power generation installations, and the projected needs were apportioned throughout the study area according to assumed service areas of the several facilities.

Rural

An estimate of the rural water use was made so as not to understate the total water requirements of the study area. For purposes of this study, rural water requirements are assumed to consist of domestic water for that portion of the rural population not served by municipal water systems, and water for the maintenance of livestock.

Irrigation

The projected use of water for irrigation was adapted from estimates of the United States Study Commission-Texas.*

Water Quality Control

Water quality control is defined as any measure employed to enhance the utility, value, and attractiveness of waters used for purposes which are affected by changes in water quality. Waters in nature are never PURE in the strict chemical sense of the word. More often than not, however, natural waters are fit for use by man in his pursuit of normal endeavors. This use and the subsequent return of waste almost always cause some degradation of water quality downstream, even after provision of highly sophisticated waste treatment. As population and the demand for water increase, this degradation of natural waters becomes increasingly worse and must be arrested before the damage becomes irreparable. Until economically feasible methods of complete waste treatment become a reality, the quality of waters can best be controlled by provision of additional water to dilute the treated wastes generated by the population. This, then is the method of water quality control with which this report is concerned, as treatment alone is not sufficient to maintain desirable stream conditions in the San Antonio River.

Of the indicators presently available for the evaluation of water quality, dissolved oxygen and total dissolved solids were chosen for use in this study. The principal causes of manmade pollution in the study area are: (a) Domestic sewage; (b) industrial wastes from food processing; (c) various other industrial wastes; and (d) irrigation return flows. All of the above contribute biochemical oxygen demand (BOD) and a variety of chemical constituents that can best be estimated as total dissolved solids. Water quality control

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*The projected values for irrigation do not represent a decision of the Public Health Service. However, they are included because (1) return flows from this source affect the quality of the study area's waters, and (2) a fully integrated water supply plan must include irrigation, especially in an area where the use represents a considerable portion of the demand on the potential water resource.

requirements are based on the assumption that sufficient waste treatment will be provided to remove 85 percent of the BOD, but none of the total dissolved solids.*

Water to regulate quality is assumed to be needed when the dissolved oxygen content of the stream drops below 4 milligrams per liter (mg/l)** and/or when the total dissolved solids reach 500 mg/l.

The determination of the quantity and quality of return flows expected to reach a stream is the first step necessary in analyzing water needs for quality control.

The quantity of municipal and industrial return flows is estimated as a percentage of water use. The municipal return flow percentage used was 62.0 percent, 23/ while industrial return flow percentages vary from 23 percent to 90 percent. 24/

The quality of municipal return flow is based on assumed per capita contributions of 0.23 pounds per day of total dissolved solids and 0.25 pounds per day of ultimate first stage BOD.

The contribution of total dissolved solids resulting from industrial use varies from 12.2 tons per million gallons to 1.2 tons per million gallons of return flow. 24/ For the BOD contribution from industry, it was assumed that final industrial effluents which discharge wastes containing BOD would have the same concentration as a municipal sewage that has been treated to remove 85 percent of the BOD. This concentration is 56 mg/l ultimate BOD, assuming a typical municipal sewage has an untreated concentration of 370 mg/l ultimate first stage BOD.

It was assumed that there would be no return flow resulting from rural water use.

Irrigation return flows were assumed to be one-third of the water applied for that purpose, and it was further assumed that all of the dissolved solids in the irrigation source water would be returned to the stream. 25/

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*With conventional treatment methods presently used, removal of some of the total dissolved solids present in the wastes probably occurs; however, this removal can be considered as incidental rather than planned and no reliable estimates of quantity so removed are available.

**The lower limit of 4 mg/l of dissolved oxygen was chosen because, (1) it is sufficient to sustain most species of fish native to this area, and (2) it provides a buffer zone to keep the streams waters from becoming anaerobic in the event that unforeseen shock loads of organic pollutants are accidently discharged to the watercourse.

In determining the amount of water from storage required to preserve the quality of the stream, it is necessary to make allowances for natural flows that can be expected to occur in the stream. Discharge frequency analyses of the streams in the basin were made from published streamflow data, which included adjustment to reflect future conditions in the basin. Calculations were then performed to determine the amount of regulation water from storage needed to maintain stream quality for hydrologic conditions that can be expected to recur in the basin streams every 20 years.

Two analyses of the basin waters, one of organic pollution (BOD), and one of chemical pollution (total dissolved solids), were made utilizing electronic computational methods where applicable.

Computations indicated that concentration of the stable pollutants (total dissolved solids) will not reach undesirable levels within the time horizon of this study.

On the other hand, organic pollution (BOD) computations revealed that waters of the San Antonio River downstream from the city of San Antonio are now and will continue to be deficient in dissolved oxygen.

Based on the previously described assumptions of organic loading, waste treatment, and hydrologic conditions; the amounts of supplemental water that will be required to maintain a minimum of 4.0 mg/l of dissolved oxygen in the waters of the San Antonio River are as shown in table VII-1 and in figure VII-1

Table VII-1

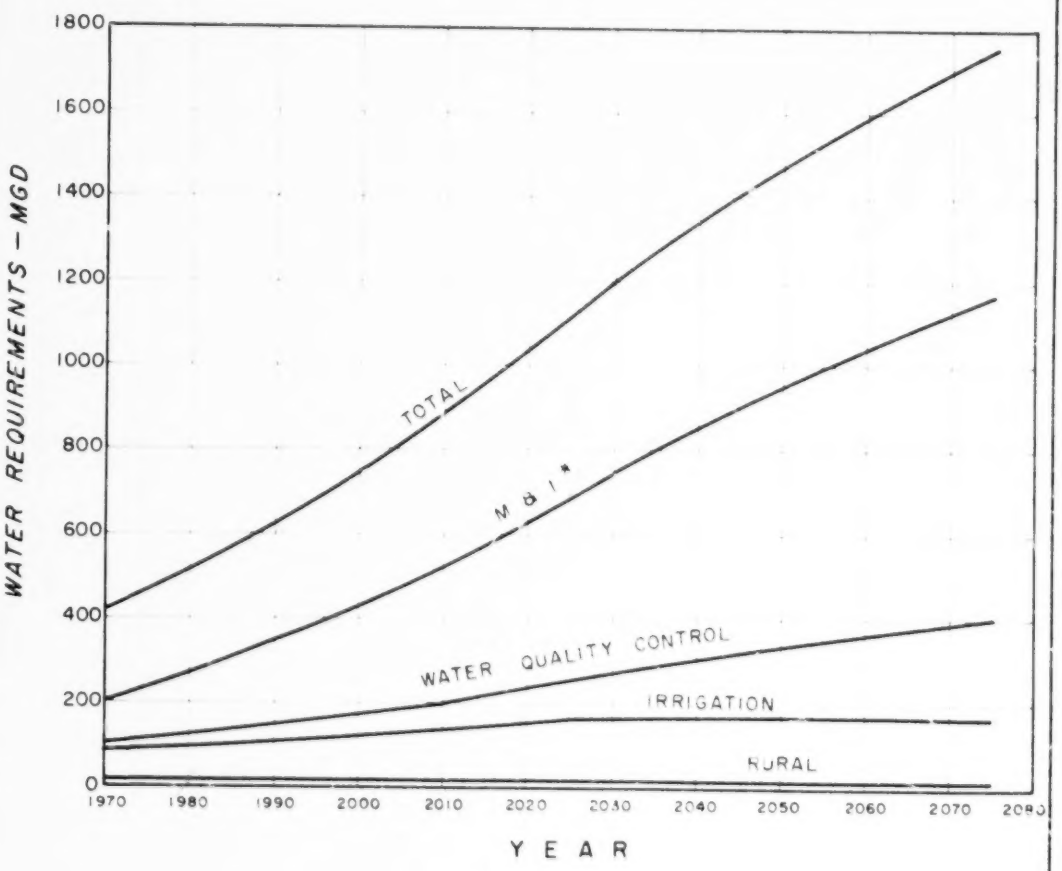
Water Quality Control Requirements

Year	Annual Draft-on-Storage in Acre-Feet/Yr. x 1,000
1970	123.0
2025	280.0
2075	454.7

No water quality problems were found in any of the other study area streams.

Base Year Water Use

The year 1958 was selected as the base for the study because it was the most recent year for which reliable data from several sources were available. The 1958 study area water use by type is shown in table VII-2.



* INCLUDES CONSUMPTIVE REQUIREMENT FOR THERMAL POWER GENERATION.

WATER SUPPLY & WATER QUALITY CONTROL STUDY
EDWARDS UNDERGROUND RESERVOIR – TEXAS

STUDY AREA WATER REQUIREMENTS

U.S. DEPARTMENT OF HEALTH, EDUCATION, & WELFARE
Public Health Service
REGION VII DALLAS, TEXAS

FIGURE VII-1-F1

Table VII-2

Base Year Water Use

	1958 Water Use (mgd)					
Subarea	Municipal	Industrial	Thermal Power Generation	Rural	Irrigation	Total
1	11.0	2.3	--	7.5	6.0	26.8
2	86.1	22.7	4.5	7.4	35.0	155.7
3	7.1	0.2	--	3.7	39.7	50.7
Study Area Total	104.2	25.2	4.5	18.6	80.7	233.2

Source: The University of Texas 22/, Public Health Service 26 30/, and Texas Board of Water Engineers 27-29/

Future Water Requirements

Estimates of future water requirements for the several types of water use in the study area were made using the technique of combining projected unit uses with economic and population projections. Irrigation water use estimates, however, are those of the U.S. Study Commission-Texas converted to suit the study area boundaries. Table VII-3 summarizes the study area water needs for the years 2025 and 2075.

Table VII-3

Projected Water Requirements

Sub-area	Water Requirements in mgd*						
	Municipal	Industrial	Thermal Power Generation	Rural	Irrigation	Water Quality Control	Total
			For the Year 2025				
1	36.4	14.0	1.4	9.3	43.9	--	105.0
2	478.8	92.3	43.3	0.5	60.6	250.0	925.5
3	14.2	8.7	--	6.0	58.4	--	87.3
TOTAL	529.4	115.0	44.7	15.8	162.9	250.0	1,117.8
			For the Year 2075				
1	63.6	27.9	2.1	9.3	43.8	--	146.7
2	819.4	151.8	66.1	0.6	60.5	406.0	1,504.4
3	22.4	13.7	--	6.8	58.5	--	101.4
TOTAL	905.4	193.4	68.2	16.7	162.8	406.0	1,752.5

*The expression of these estimates to tenths of an mgd is not intended to imply precision. Since this table is the resultant addition of many individual values, several of which are less than one mgd, the use of tenths eliminates rounding and the loss of identity of the several smaller water uses.

A graphical presentation of water requirements in the study area is shown in figure VII-1.

VIII. WATER SUPPLY AND WATER QUALITY CONTROL PLAN

General

In order to supply the water needs shown in the previous section, a plan is presented utilizing all available water resources in the Edwards Underground Reservoir area of Texas, including the tentative import of water from Cuero Reservoir.

Water Availability

With the project features in operation, the water resources of the study area in the year 2025 are as follows:

	Yield (mgd)
Surface:	
Cloptin Crossing Reservoir	38.0
Dam 7 Reservoir	41.0
Canyon Reservoir	86.0
Run of Stream Sources a/	32
Montell Reservoir b/	4.0
Cuero Reservoir c/	161.0
Ground:	
Edwards Underground Reservoir pumpage d/	235
San Marcos Spring e/	36
Other ground water resources f/	22
Municipal and Industrial Return Flow directly utilized (varying quantity 1960-2025) g/	13 - 127
	782

a/Used primarily for irrigation; yield based on 98 percent exceedence interval of annual flows.

b/Used to satisfy future downstream municipal and industrial requirements.

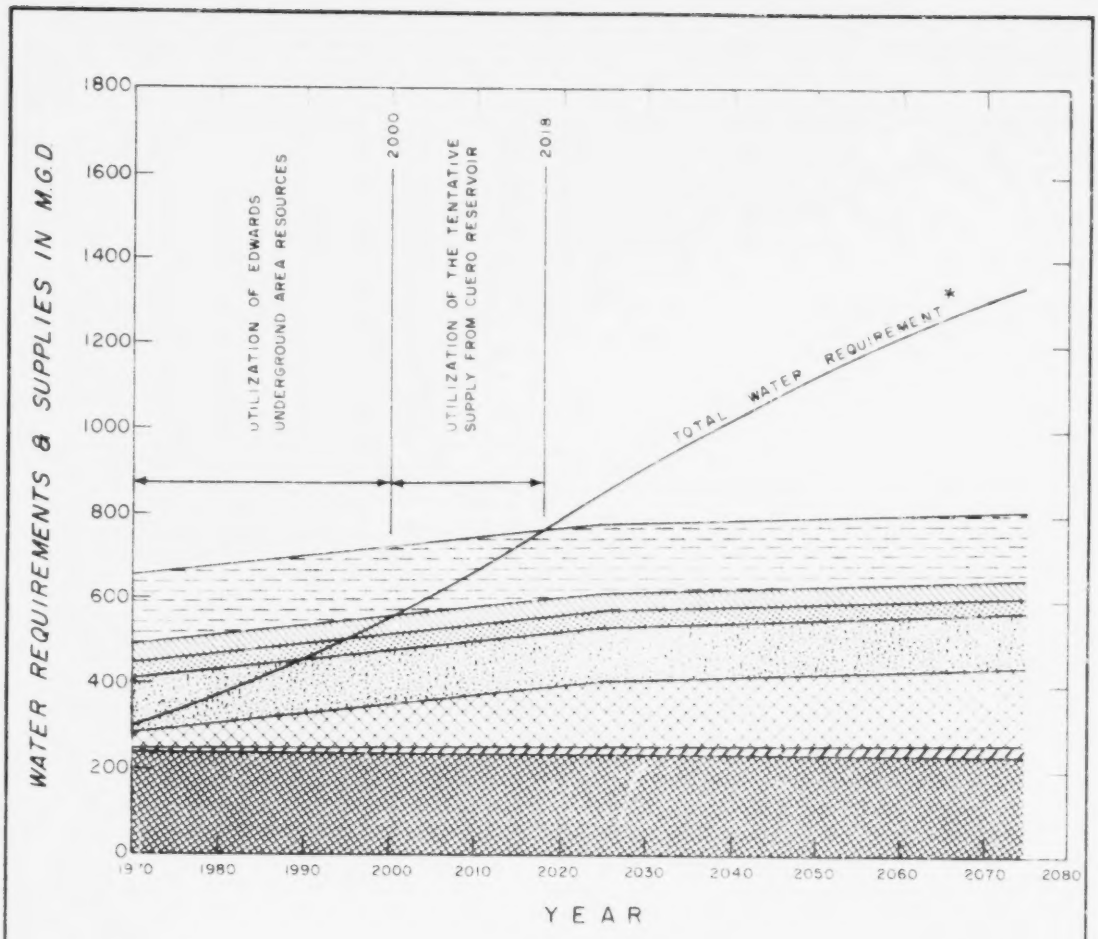
c/Total dependable yield of 300 mgd based on Bureau of Reclamation routing.

d/Based on Corps of Engineers' routing.

e/Dependable flow from San Marcos Spring based on Corps of Engineers' routing.

f/Estimated development in Carrizo-Wilcox sands, Edwards limestone-Trinity sands aquifer and use of Las Moras Spring.

g/Used to satisfy requirements for irrigation and thermal power generation.



* Total water requirement includes municipal, industrial, thermal power generation, rural, and irrigation uses. Water quality control requirements are not included.

a/ Estimated development in Carrizo Wilcox sands, Edwards Limestone – Trinity sands aquifers and use of Las Moras Spring

b/ Used primarily for irrigation and thermal power generation

WATER SUPPLY & WATER QUALITY CONTROL STUDY
EDWARDS UNDERGROUND RESERVOIR – TEXAS

STUDY AREA WATER AVAILABILITY
(INCLUDING THE TENTATIVELY AGREED IMPORT FROM CUERO RESERVOIR)

U.S. DEPARTMENT OF HEALTH, EDUCATION, & WELFARE
Public Health Service
REGION VII DALLAS, TEXAS

FIGURE VIII-1

As discussed in Section VII, the draft-on-storage required for the San Antonio River downstream from San Antonio varies from 123,000 acre-feet/year in 1970; to 280,000 acre-feet/year in 2025; to 454,700 acre-feet/year in 2075. Due to the nature of or locations of the resources listed above their use for water quality control purposes is doubtful. Of the four Federal projects, three (Montell, Concan, and Sabinal Reservoirs) are for ground water recharge located far from the point of need for water quality control. The nature of their design rules out use of these reservoirs for water quality control. Cloptin Crossing, the remaining Federal reservoir is dropped from further consideration for water quality control in the foreseeable future, since its entire dependable yield (38 mgd) is proposed for municipal and industrial uses by the Guadalupe-Blanco River Authority and its location is also far from the point of need. Even if it were available, this reservoir could provide only about one-third of the 1970 water quality control requirement.

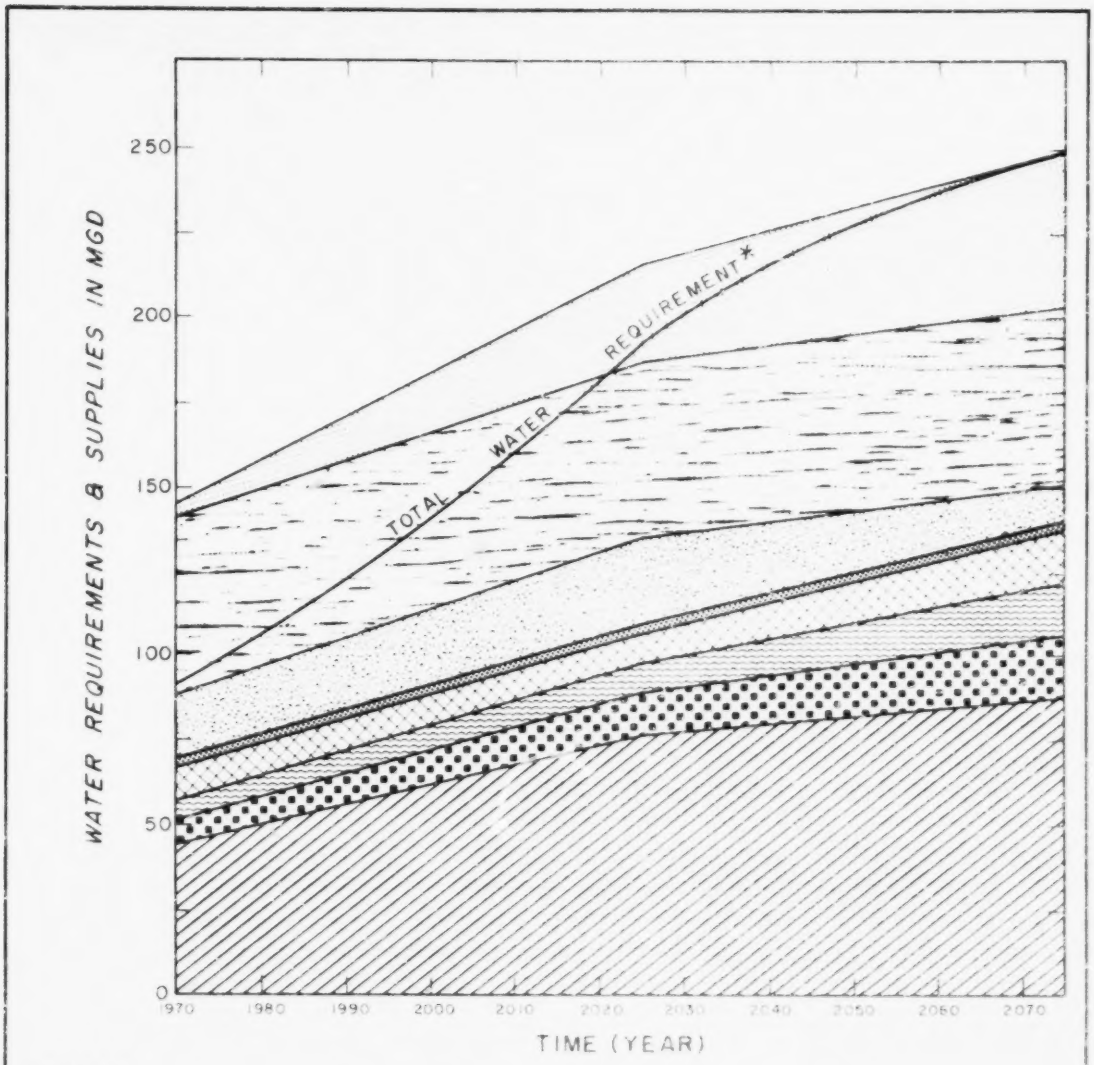
It is concluded, therefore, that under the stated assumptions of waste treatment and hydrologic conditions, the San Antonio River will be practically devoid of oxygen for about 110 miles downstream from the city of San Antonio by the year 2025. This situation may be ameliorated by the future development of highly efficient advanced waste treatment and water reuse techniques. If left unchecked, however, such conditions would create a public health hazard and nuisance and severely curtail the utility of these waters, resulting in damages to fish and wildlife, loss or downgrading of recreational opportunities, and restrictions of probable economic activities.

An over-plot of these resources on the total requirement curve of figure VII-1 (excluding water quality control) shows that the area's resources will satisfy the total water requirements until approximately the year 2000. (See figure VIII-1.)

Addition of the tentative quantity of 161 mgd from Cuero Reservoir on the Guadalupe River [31/] will make it possible to meet all area water needs excluding water quality control until the year 2018.

A closer examination of the future water requirements shows that it is the San Antonio SMSA (Bexar County) which will suffer the shortages. A graph of needs and resources versus time for the area excluding Bexar County indicates that its water requirements can be satisfied for the entire length of the projection period. (See figure VIII-2.)

If the San Antonio area is to grow and prosper beyond the year 2018, it is imperative that additional sources of water be made available. The location of such sources, however, is beyond the scope of this report.



LEGEND

- EDWARDS LIMESTONE
- EDWARDS–TRINITY LIMESTONE
- CARRIZO–WILCOX SANDS
- SAN MARCOS SPRING
- LAS MORAS SPRING
- RUN OF STREAM SUPPLIES
- CANYON & DAM No. 7 RESERVOIRS
- REUSE OF M & I RETURN FLOWS

*TOTAL WATER REQUIREMENT INCLUDES MUNICIPAL, INDUSTRIAL, THERMAL POWER GENERATION, RURAL, AND IRRIGATION USES. THERE IS NO WATER QUALITY CONTROL REQUIREMENT IN THIS CASE.

WATER SUPPLY & WATER QUALITY CONTROL STUDY

EDWARDS UNDERGROUND RESERVOIR – TEXAS

STUDY AREA WATER AVAILABILITY EXCLUDING SAN ANTONIO S.M.S.A.

U.S. DEPARTMENT OF HEALTH, EDUCATION, & WELFARE

Public Health Service

REGION VII DALLAS, TEXAS

FIGURE VIII-2

IX. BENEFITS

Senate Document No. 97 (87th Congress, 2nd sess.) makes the following statement concerning evaluation of benefits of municipal and industrial water supply storage in Federal reservoirs:

> "The amount water users should be willing to pay for such improvements in lieu of foregoing them affords an appropriate measure of this value. In practice, however, the measure of the benefit will be approximated by the cost of achieving the same results by the most likely alternative means that would be utilized in the absence of the project."

This alternative cost method was used to evaluate storage for municipal and industrial use in the three recharge reservoirs as well as the conventional multiple-purpose reservoirs. The values determined in this way are considered to be the minimum annual values of the benefits.

Alternative Plans Considered

Although the study area is underlain by an excellent aquifer, it is relatively short of water as shown in the previous discussion. Three of the four project reservoirs are designed to increase the yield of the Edwards Underground Reservoir. The remaining reservoir, Cloptin Crossing, plus local interest development represent all of the area's surface water resources which can be economically developed at the present time. A tentative local plan provides for the importation of water from the proposed Cuero Reservoir on the Guadalupe River; however, additional importation from surrounding basins, although remotely possible, seems infeasible at this time due to area politics.

After investigation of various possibilities, a single-purpose reservoir at the site of Cloptin Crossing Reservoir was adopted as the most reasonable alternative to this project. This single-purpose project was assumed to have a yield equal to the yield expected from the storage to be provided for municipal and industrial water supply purposes in the proposed multipurpose reservoir.

For the three recharge reservoirs, the most reasonable alternative adopted was water from the proposed Cuero Reservoir on the Guadalupe River. The benefits for these reservoirs were evaluated as being equal to the cost of delivered water from the alternative source (Cuero Reservoir) taking into account the differential costs

of pumping and treatment. 31/ Benefits are calculated only for the increase in water available for pumping and the increased spring flow from the fault zone aquifer which results from these recharge reservoirs.

A summary of the annual project benefits is shown in table IX-1. The methods of calculation used for the benefit evaluation are shown in the Appendix. Since all of the reservoirs are needed as soon as possible, no discounting of the benefits is made. Values shown represent present worth in the year 1970.

Table IX-1

Summary of Value of Water Supply Benefits

Reservoir	Dependable Yield (mgd)	Value	
		Annual (1970 $)	Equivalent Cents per 1,000 gal.
Cloptin Crossing	38.0	$ 653,000	4.7
Montell: Downstream	4.0*	$ 88,300	6.0*
Recharge	-0-	$1,010,500	11.7**
Concan	-0-	$ 816,800	11.7**
Sabinal	-0-	$ 600,100	11.7**

* The dependable yield of Montell Reservoir is used to satisfy future downstream municipal and industrial water requirements. The benefit for this function of the reservoir is based on the most reasonable alternative. (See Appendix)

** Based on prorated increase in resource of Edwards Underground Reservoir. (See Appendix)

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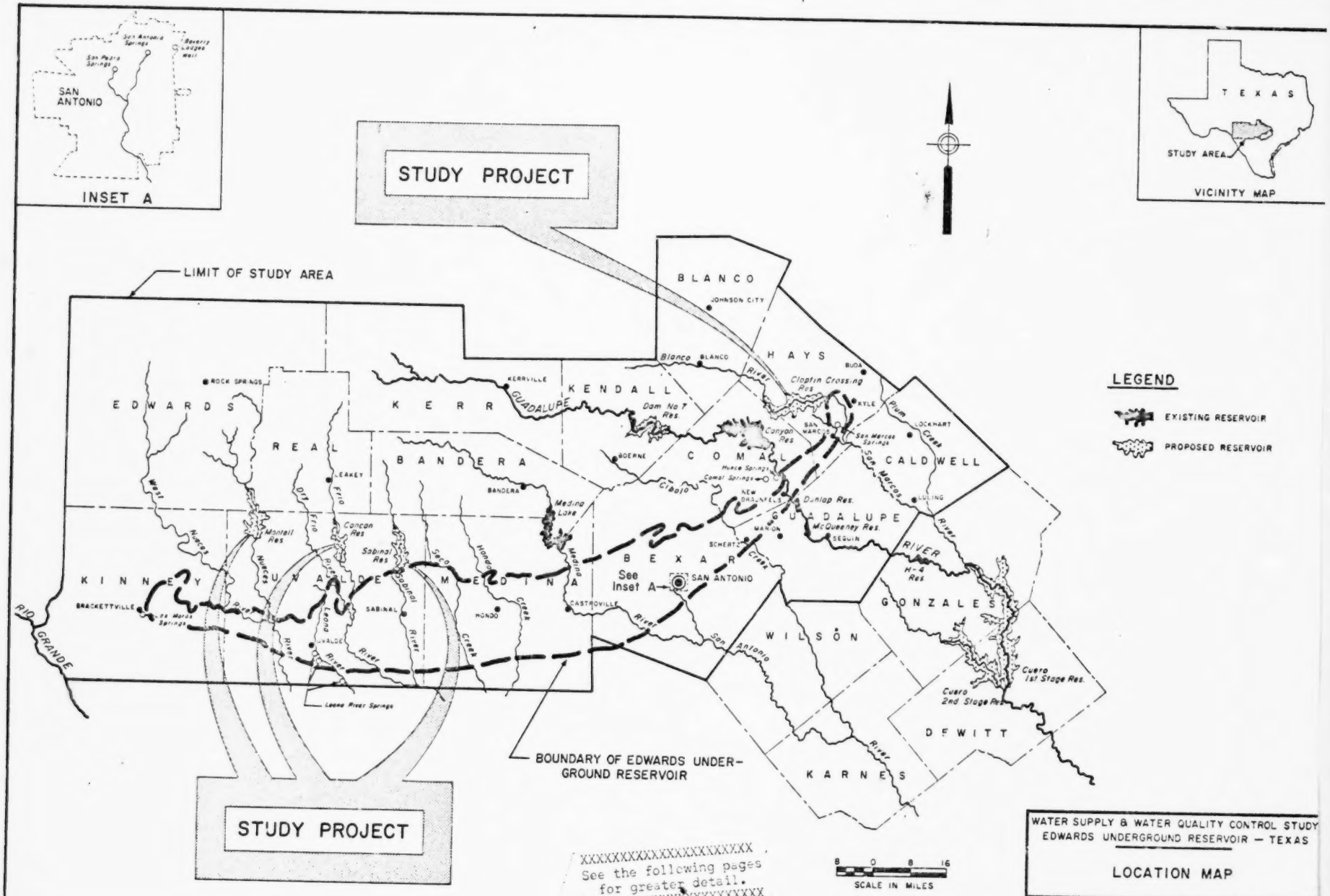


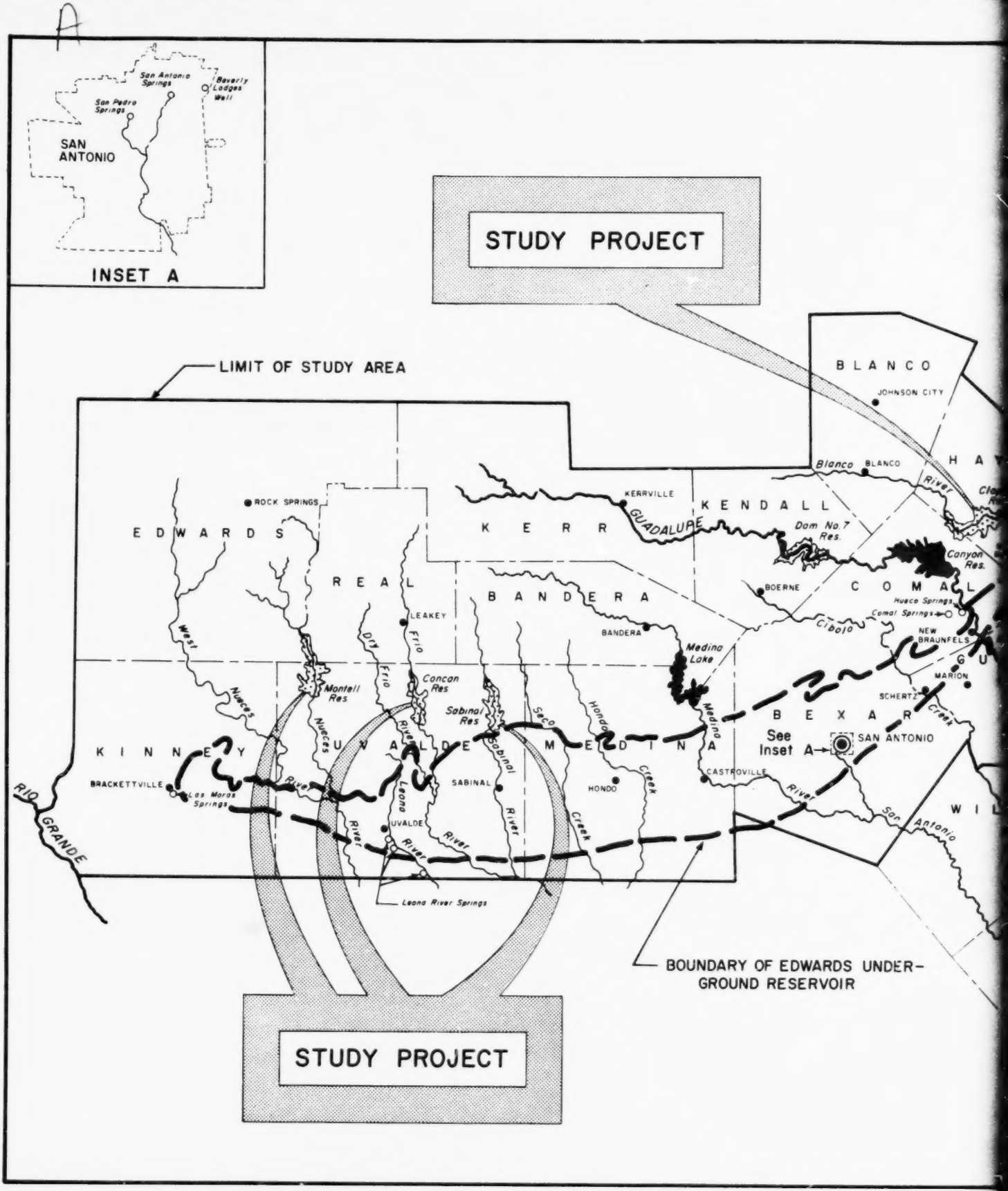
WATER SUPPLY & WATER QUALITY CONTROL STUDY
EDWARDS UNDERGROUND RESERVOIR — TEXAS

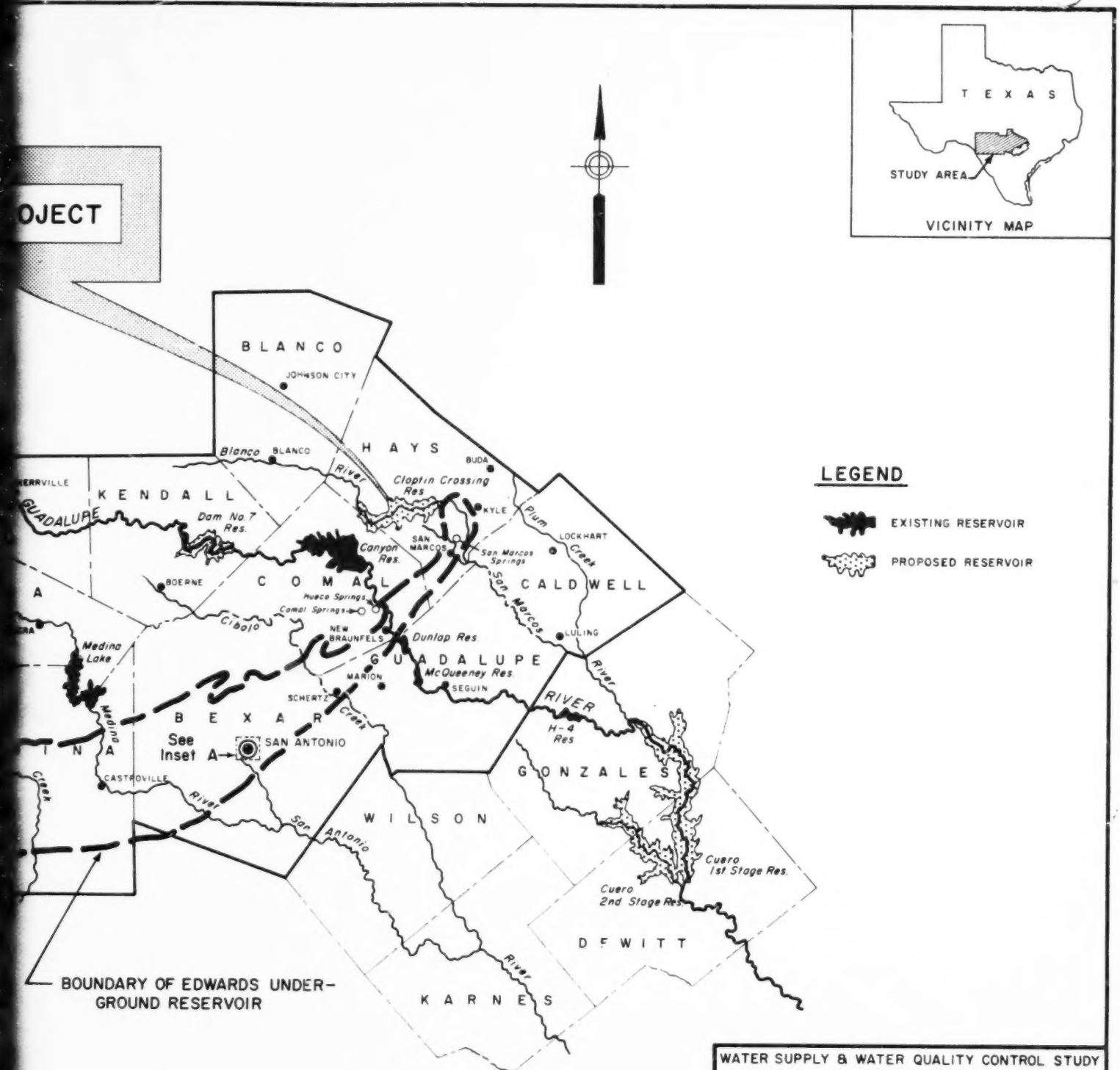
LOCATION MAP

U.S DEPARTMENT OF HEALTH, EDUCATION & WELFARE
Public Health Service
REGION VII DALLAS, TEXAS

X-4

FIGURE III-1


INSET A
San Antonio Springs
Beverly Lodges Well
San Pedro Springs
SAN ANTONIO
STUDY PROJECT
LIMIT OF STUDY AREA
BLANCO
JOHNSON CITY
Blanco
BLANCO
River
KERRVILLE
KENDALL
GUADALUPE
Dam No. 7 Res.
Canyon Res.
ROCK SPRINGS
EDWARDS
KERR
REAL
BANDERA
BOERNE
COMAL
Huaco Springs
Comal Springs
Cibolo
LEAKEY
BANDERA
NEW BRAUNFELS
Medina Lake
West Nueces River
Dry Frio River
Frio River
Nueces River
Montell Res
Concan Res
Sabinal Res
Seco Creek
Hondo Creek
Medina River
MARION
SCHERTZ
Cibolo Creek
BEXAR
See Inset A
SAN ANTONIO
KINNEY
UVALDE
MEDINA
BRACKETTVILLE
Las Moras Springs
Leona River
SABINAL
HONDO
CASTROVILLE
San Antonio River
RIO GRANDE
UVALDE
Sabinal River
Leona River Springs
BOUNDARY OF EDWARDS UNDER-GROUND RESERVOIR
STUDY PROJECT



WATER SUPPLY & WATER QUALITY CONTROL STUDY
EDWARDS UNDERGROUND RESERVOIR — TEXAS

LOCATION MAP

U. S DEPARTMENT OF HEALTH, EDUCATION & WELFARE
Public Health Service
REGION VII DALLAS, TEXAS

X-4

FIGURE III — 1

APPENDIX - A

APPENDIX

Benefit Calculations

CLOPTIN CROSSING RESERVOIR PROJECT

Most reasonable alternative: Single-purpose reservoir with a yield from storage of 38.0 mgd.

Estimated first cost	$15,670,000
Estimated interest during construction	1,175,000
Estimated total investment	$16,845,000

Amortize private investment for 25 years at 4 percent
(16,845,000)(0.06401) = $1,078,248 per year

Convert to equivalent Federal investment to provide for same annual payment.

Present worth of 1 per period @ 3 1/8 percent = 17.17308

Then equivalent Federal investment =
(1,078,248)(17.17308) = 18,516,839

Amortize Federal investment for 100 years at 3 1/8 percent

Annual Cost = (18,516,839)(0.03276)	=	$606,612
Estimated annual operation and maintenance	=	46,000
Annual benefit	=	$652,612
Say		$653,000

MONTELL RESERVOIR, SABINAL RESERVOIR, AND CONCAN RESERVOIR PROJECTS

Most reasonable alternative to increase in pumping potential = Cost of delivered water from another source (Cuero Reservoir) + Cost of pumping ground water + Treatment differential (Cuero less ground)

Increase in yield of Edwards limestone aquifer for pumping = 29,000 acre-feet per year or 25.9 mgd. 1/

Estimated treatment plant cost for 25.9 mgd = $2,976,100

Amortize private investment for 25 years @ 4 percent
(2,976,100)(0.06401) = $190,500

Convert to equivalent Federal investment to provide for same annual payment

Present worth of 1 per period @ 3 1/8 percent = 17.17308

Then equivalent Federal investment =
(190,500)(17.17308) = $3,272,300

Amortize Federal investment for 100 years @ 3 1/8 percent

Annual Cost = (3,272,300)(0.03276) = $107,200

Estimated Annual Operation & Maintenance = 261,500

Annual Cost $368,700

or on a unit basis = 3.9¢ per 1,000 gallons

Estimated ground water pumping cost = 2.4¢ per 1,000 gallons

Estimated ground water chlorination cost = 0.2¢ per 1,000 gal.

Cuero Reservoir water delivered cost 3/ = 12.3¢ per 1,000 gal.

Therefore: Unit benefit for pumping =

12.3 - 2.4 + (3.9 - 0.2) = 13.6¢ per 1,000 gallons

Increase in Spring flow from San Antonio and San Pedro Springs

Value of most reasonable alternative to increase in spring flow from San Antonio and San Pedro Springs is the same as that for pumping in the San Antonio area plus the cost of pumping ground water (no delivery cost is involved; therefore, the 2.4¢/1,000 gallons cost of pumping must be re-added.)

Therefore: Unit benefit for San Antonio & San Pedro Springs =
13.6 + 2.4 = 16.0¢/1,000 gallons

Increase in Spring flow from San Marcos, Comal, and Hueco Springs

Value of most reasonable alternative to increased spring flow from San Marcos, Comal, and Hueco Springs = Delivered cost of Cuero water 31/ - Cost of transmission from springs to San Antonio.

From curve of cost vs. capacity for transmission from Comal and San Marcos Springs to San Antonio: 1/ for 17,600 AF/yr or 15.7 mgd cost = 5.0¢ per 1,000 gal.

Unit benefit for increased spring flow = 12.3 - 5.0 = 7.3¢ per 1,000 gal.

Increase in Spring flow from Leona River Springs

The discharge of the Leona River Springs percolates into the Leona formation, a shallow aquifer overlying the Edwards limestone. The value of this increase in spring flow is based on obtaining an equal amount of water from the deeper Edwards limestone formation. The quality of both waters is approximately the same.

Increased spring flow = 4,000 acre-feet per year = 3.57 mgd 1/

300' x 8", 150 gpm well including testing and pump house = $16,000 32/

3.57 mgd = 2,500 gpm ∴ 17 wells needed

Total Cost	=	$272,000
Pump and motor @ $3,000 per well 32/	=	51,000
Well field collection system	=	294,100
Total first cost		$617,100

Amortize private investment for 25 years @ 4 percent
(617,100)(.06401) = $39,500

Convert to equivalent Federal investment @ 3 1/8 percent for 100 years
39,500 (17.17308)(.03276) = $22,200 per year

Annual Energy Cost = $\frac{100' \text{ head } (.00315)}{.85}$ (1,303,050 thousand gal./yr) ($.006/kwh) = $2,900

Annual Operation and Maintenance =	$1,000
Total Annual Cost =	$26,100

or unit value of Leona River Springs water = 2.0¢/1000 gal.

Increase in resources:	Acre-feet/yr. 1/	Percent 1/
Total	63,900	100.00
Montell Reservoir	26,600	41.63
Concan Reservoir	21,500	33.65
Sabinal Reservoir	15,800	24.72

Annual benefit for increased pumping potential
29,000 AF/yr = 9,449,679 (1000 gal/yr) @ 13.6¢ = $1,285,500

Prorating:		
	Montell	$535,200
	Concan	$432,600
	Sabinal	$317,700

Annual benefit for increased spring flow from Comal, San Marcos and Hueco Springs
17,600 AF/yr = 5,736,632 (1,000 gal/yr) @ 7.3¢ = $418,800

Prorating:		
	Montell	$174,300
	Concan	$140,900
	Sabinal	$103,600

Annual benefit for increased spring flow from San Antonio and San Pedro Springs
13,300 AF/yr = 4,335,069 (1,000 gal/yr) @ 16.0¢ = $693,600

Prorating:		
	Montell	$288,700
	Concan	$233,400
	Sabinal	$171,500

Annual benefit for increased spring flow from Leona River Springs
4,000 AF/yr = 1,303,050 (1,000 gal/yr) @ 2.0¢ = $26,100

Prorating:		
	Montell	$10,900
	Concan	$ 8,800
	Sabinal	$ 6,400

Decrease in Pumping Head

Another creditable benefit is realized from reduced pumping head in the underground reservoir.

Average reduction in total head - 1.79 feet 1/

Total pumpage = 263,000 AF/yr = 85,723,535 (1,000 gal/yr)

Assumed pump efficiency = 85 percent

Assumed energy cost = $0.006 per kwh

Annual kwh = $\frac{1.79\ (.00315)}{0.85}$ (85,723,535) = 568,700

Annual electrical saving = 568,700 (.006) = $3,400

Prorating	Montell	$1,400
	Concan	$1,100
	Sabinal	$ 900

Summary of Annual Recharge Benefits for Montell, Concan, and Sabinal Reservoirs

Reservoir	Increased Pumping Potential	Increased Spring Flow: Comal, San Marcos & Hueco	Increased Spring Flow: San Antonio & San Pedro	Increased Spring Flow: Leona River	Decreased Pumping Head	Total
Montell	$535,200	$174,300	$288,700	$10,900	$1,400	$1,010,500
Concan	432,600	140,900	233,400	8,800	1,100	816,800
Sabinal	317,700	103,600	171,500	6,400	900	600,100
TOTAL	$1,285,500	$418,800	$693,600	$26,100	$3,400	$2,427,400

An additional benefit from Montell Reservoir is to the downstream municipal and industrial water users who will receive 4.0 mgd via a pipeline. The most reasonable alternative to this part of the project is a single-purpose reservoir to yield 4.0 mgd.

The estimated cost of this alternative is $2,358,000

Annual Operation and Maintenance is estimated to be $3,400

Amortize private investment for 25 years @ 4 percent
2,358,000 (0.06401) = $150,900

Convert to equivalent Federal investment to provide for same annual payment.

Present worth of 1 per period @ 3 1/8 percent = 17.17308

Then equivalent Federal investment =
($150,900)(17.17308) = $2,591,400

Amortize Federal investment for 100 years @ 3 1/8 percent

Annual Cost = (2,591,400)(0.03276) = $84,900

Estimated Annual Operation and Maintenance 3,400

∴ Annual Benefit = $88,300